Financial Implications of Imbalance Settlement Exemptions for Wind Power Generators

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***Abstract*—This paper evaluates the application of the specific Belgian mechanism to relief offshore wind power generation partially from the imbalance settlement mechanism. A tolerance margin for imbalances originating from offshore production deviations is installed in which producers and balancing responsible parties enjoy beneficial imbalance tariffs.**

This paper investigates background, conditions and financial implications of this regulation in order to determine if such support mechanisms can be adequate to support offshore wind power developments.

***Index Terms*—imbalance settlement, offshore wind power, support mechanism, wind power integration**

I. Introduction: Wind Power and Imbalance Settlement

ONE of the main limitations for exploiting large shares of wind power generation is its variability. This power source depends on a variable input resulting in an output characterised by a limited controllability. Furthermore, wind power has a limited predictability.

On the other hand, wind energy faces an electricity system which needs an instant balance between demand and supply. Combined with other characteristics such as limited storability and variable consumption, this requires a certain control over generation and/or consumption. One of the main challenges concerning wind power integration is consequently to balance (unpredicted) output fluctuations originating from the increasing shares of wind power in the electricity grid.

To incentivise system balance, most power systems introduced imbalance settlement mechanisms [1]. Therefore, all market players operating in the Belgian electricity market are obliged to have a contract with a balancing responsible party (BRP). This BRP aggregates different market participants and maintains its portfolio in balance by ensuring that injections match off-takes for every 15 minutes. In order for the transmission system operator (TSO) to plan grid operations, these positions have to be sent as nominations to the TSO before gate closure, generally one day in advance.

After this deadline, nominations can generally not be altered anymore. However, some tools exist to manage expected imbalances after gate closure due to the availability of new information. These are specifically dealt with in another paper written by the author [2].

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When a BRP's portfolio is not in balance at real-time, the BRP has to pay the imbalance tariff for the aggregated imbalances in its portfolio. If the total control zone (aggregation of all BRPs) is not in balance at real time, the TSO, as final responsible for the grid security, activates available reserve capacity in order to restore system balance.

The imbalance settlement mechanism in Belgium is transparently available on the website of the TSO [3] and is represented in Table 1.

Table 1 If a BRP faces a negative imbalance (injections + import + purchase < off-take + export + sales), it is said to be short and is consequently required to buy the missing electricity from the system operator above market price. On the other hand, if the BRP's position is long, it has to sell its surplus to Elia under the market price. These imbalance tariffs are in best case 92% or 108% of the Belpex Day Ahead Market (Belpex DAM) price when the BRP's imbalance counteracts with the system imbalance. In the other case, when the imbalance reinforces the system imbalance, the imbalance tariff is equal or lower than 92% or equal or higher than 108% and introduces an extra uncertain cost (risk) which depends on the volume and cost of the activated regulating reserves.

TABLE 1
IMBALANCE TARIFFS IN THE BELGIAN CONTROL ZONE (SOURCE: ELIA)

	Positive system imbalance	**Negative system imbalance**
Positive imbalance BRP (injection > off-take)	• Max. 0.92 * Belpex DAM • Variable tariff depending on: 1. Downward regulation volume 2. Average downward regulation price 3. Activated downward regulation price	0,92 * Belpex DAM
Negative imbalance BRP (injection < off-take)	1,08 * Belpex DAM	• Min. 1.08 * Belpex DAM • Variable tariff depending on: 1. Upward regulation volume 2. Average upward regulation price 3. Activated upward regulation price

This system implies an additional cost for wind power generators which results from their inability to predict and nominate exactly the injection of wind generation. BRPs have to balance their positions with available flexible generation (portfolio or on the market) or face the imbalance tariff. This is not entirely new to the BRPs as they already gained experience with imbalances caused by load variations and power plant outages. However, experience with variable power sources is relatively new and while prediction tools are improving but still inaccurate. For a single wind power plant day-ahead output forecasts are characterised with a mean absolute error of 20% which may decrease until 5-7% one or two hours before real-time [4].

To promote the integration of offshore wind power in Belgium, a specific support mechanism was installed aiming to reduce imbalance costs. This mechanism is based on a tolerance margin in which offshore wind power enjoys reduced imbalance tariffs.

II. Belgian Tolerance Margin for Offshore Wind Power Production

A framework for this tolerance margin was shaped in the Royal Decree of 19 December 2002 (Grid Code). Article 317 introduces the concept for renewable and CHP installations. The specific implementation of this article was however not yet defined. This was done later by the Royal Decree of March 30, 2009, stipulating the execution of such tolerance margin for offshore wind power generation [5],[6]. This regulation came into force June, 3, 2009 and targets specifically deviations of production (difference between the nominated and the measured output, expressed in kW) originating from offshore wind power plants. It is settled per 15 minutes, per individual concession (Art. 2, KB 30/03/2009).

It may be important to clarify the terminology of the "production deviation" used in this legislation. The meaning is explained in Art. 2 and refers to the difference between the nominated and the real-time measured power output. In case of wind power, the nominated output is generally determined by the predictions. It is important to emphasize the difference with the concept of imbalance which refers to the difference between injections and off-takes in a BRP's portfolio. This encompasses the sum of all generation and load deviations.

The core of this regulation is that for an individual offshore wind power plant, imbalances originating from offshore production deviations up to 30% of the nominated offshore capacity are to be bought or sold by Elia respectively at 90% or 110% of the Belpex Day-Ahead Market (DAM) reference market price. This mechanism is in fact similar to the normal imbalance settlement mechanism, except that now, when the wind farms' production deviation reinforces the overall system imbalance, higher uncertain tariffs may be avoided. The remaining part of energy which corresponds to a production deviation exceeding the 30% margin is again subject to the normal imbalance settlement tariffs shown in Table 1.

The mechanism is illustrated in Fig. 1 and Table 2: if for an offshore wind power plant, 200 MW is nominated for the first part of the day, all deviations inside 140 MW and 260 MW are settled with Elia at the advantageous tariff (90% / 110% of the Belpex DAM price). A positive imbalance, for instance a real-time production of 280 MW at 7h00, is only for 20 MW subject to the normal imbalance settlement which might be higher than 10% of the market reference price. The first 60 MW however falls within the tolerance margin.

Table 3 and Table 4 built on the previous example by attaching the relevant imbalance tariffs. A situation is assumed where a BRP's imbalance is entirely originating from the production deviation of an offshore wind power plant. This wind power plant faces an electricity price of 40 €/MWh on the Belpex DAM and imbalance tariffs of 20/60 €/MWh when the imbalance reinforces the system imbalance.

Comparing a scenario without (Table 3) and with (Table 4) tolerance margin, it can be seen that the regulation is specifically advantageous in situations where the BRP's imbalance reinforces the system imbalance. Otherwise, when counter-acting on the system imbalance, wind power deviations falling under the tolerance margin are paid systematically 2% more in comparison with the normal settlement mechanism. Although the tolerance margin puts the wind power producer in disadvantage in these situations, this is largely compensated by the tariff reductions in the other case.

To ensure grid stability, such support mechanism cannot be allowed to harm the incentive of the generator to minimise imbalances. This is assured in the regulation with a few specific conditions:

-- The best forecasting tools available at reasonable price must be applied (Art. 4) after which the most accurate forecasts have to be nominated (Art. 2). Results and methods for forecasting must be extensively communicated with the grid operator (Art. 4).

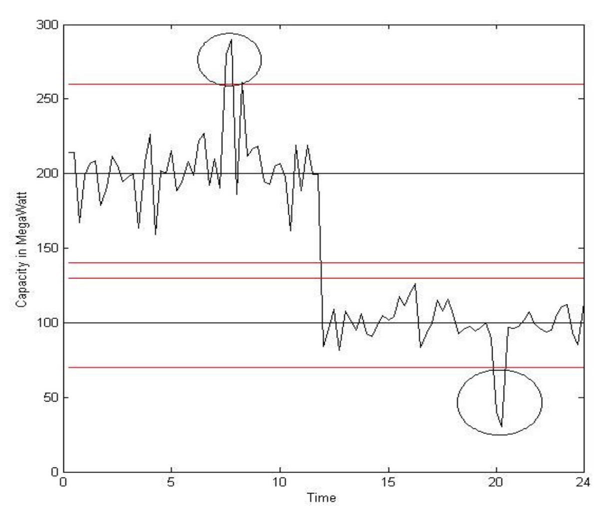

Fig. 1 Tolerance margin of 30% for offshore nomination of 200 MW (0h00-12h00) and 100 MW (12h00-24h00).

TABLE 2
IMBALANCE TARIFFS IN THE BELGIAN CONTROL ZONE (SOURCE: ELIA)

	≤ 30 %	> 30 % Negative system imbalance	> 30 % Positive System Imbalance
Positive imbalance BRP	0,90 * Belpex DAM	0,92 * Belpex DAM	≤ 0,92 * Belpex DAM
Negative imbalance BRP	1,10 * Belpex DAM	≥ 1,08 * Belpex DAM	1,08 * Belpex DAM

TABLE 3
IMBALANCE COSTS FOR A WIND FARM WITHOUT 30% TOLERANCE MARGIN

	Positive system imbalance	Negative system Imbalance
Positive imbalance BRP (80 MW)	80 MW * €20 = €1600	80 MW * 92% * 40€ = €2944
Negative imbalance BRP (80 MW)	80 MW * 108% * -40€ = €-3456	80 MW * €-60 = €-4800

TABLE 4
IMBALANCE COSTS FOR A WIND FARM WITH 30% TOLERANCE MARGIN

	Positive system imbalance	Negative system Imbalance
Positive imbalance BRP (80 MW)	60 MW * 90% * €40 + 20 MW * €20 = €2560	60 MW * 90% * €40 + 20 MW * 92% * €40 = €2896
Negative imbalance BRP (80 MW)	60 MW * 110% * €-40 + 20 MW * 108% * €-20 = €-3504	60 MW * 110% * €-40 + 20 MW * €-60 = €-3840

-- The transmission system operator respectively buys or sells the surplus or shortage of electrical energy caused by the imbalance at the Belpex reference market price (Art. 6) decreased or increased with 10%. This means that the generator is still penalised for its imbalance and the incentive to minimise is maintained.

-- If the Intra-day Production mechanism is applied, the adapted nomination is used as a reference to calculate the deviation (Art. 3). The Intra-day Production mechanism (in place from 2009) allows a generator to change its nomination intra-day provided that the system operator approves this change. The new nomination has to be between the value of the last nomination and the prediction at the moment of submitting the intra-day nomination.

A few critical remarks concerning this mechanism are to be made: first the advantageous tariffs are not consistent with the tariffs of the imbalance settlement. When this regulation was designed the minimum tariffs of the imbalance settlement mechanism were 90% or 110% of the market reference price. A few years ago, the general imbalance tariffs were adapted to 92% and 108% which is not altered in the tolerance margin mechanism.

A second remark is that the contractual structure of this regulation is rather complex (Fig. 2). The imbalance settlement mechanism is generally a relation between the BRP and the TSO as described in the previous section. This relation is largely maintained when applying the tolerance margin (Art. 5). The BRP nominates and balances its position and is

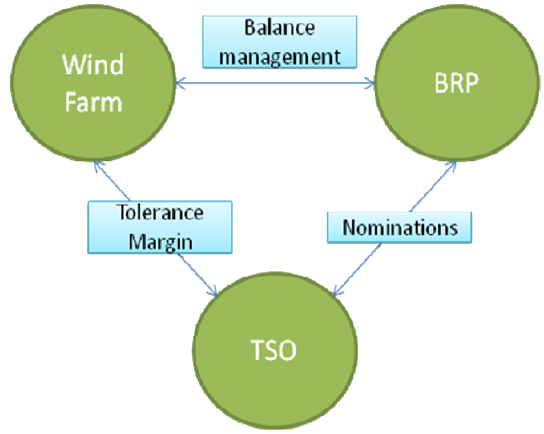

Fig. 2 Contractual representation of the 30% tolerance margin

accountable for the aggregated imbalance of its portfolio. However, offshore deviations falling under the tolerance margin are bought or sold by the TSO from the concession holder (Art. 6). This results in a contractual relation between the TSO and the wind farm concession holder. The reference, the nomination is again delivered by the BRP (day-ahead, intra-day). These nominations submitted by the BRP are binding for the wind park concessionaire (Art. 7). The complexity of this relationship is that now, the BRP as well as the wind park developer become accountable for their deviations. This complexity can however be reduced if the concessionaire transfers all rights and duties concerning this rule to his BRP (Art. 7).

A similar tolerance margin was installed in Spain with the second regulation (Spanish Royal Decree 436/2004). All wind power plants larger than 10 MW applying the feed-in tariff were obliged to predict the power output for every 60 minutes before 18h00 D-2. The absolute error between prediction and production was subject to an imbalance tariff when exceeding a tolerance margin of 20% [7]. This support mechanism disappeared in the third regulation (Royal Decree 661/2007). Wind power imbalances are today treated in the same way as under the feed-in premium system, it is namely fully responsible for its imbalances.

III. PREDICTABILITY AND PRODUCTION DEVIATIONS OF OFFSHORE WIND POWER PLANTS

In this section, the underlying motivation of the 30%-mechanism is briefly discussed, namely the higher unpredictability of wind resources at offshore locations. This assumption is often used as an argument by the advocates of the offshore tolerance margin.

In order to address this research target, a preliminary analysis was performed for the North Sea area by the author in a separate paper [8]. Prediction error and resulting production deviations from five locations in the Netherlands were compared: two offshore locations (Vlakte Van De Raan and Lichteiland Goeree) are compared with three onshore sites (Eindhoven, Woensdrecht and Stavenisse) (Fig. 3) [9][10].

Three common indicators are used to evaluate wind speed/power prediction errors:

-- Average error over the evaluation period (BIAS):

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}(X_{predicted,i} - X_{measured,i}) \tag{1}$$

-- Mean Absolute Error (MAE):

$$MAE = \frac{1}{N}\sum_{i=1}^{N}| X_{predicted,i} - X_{measured,i} | \tag{2}$$

-- Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_{predicted,i} - X_{measured,i})^2} \tag{3}$$

Results are summarised in Table 5 and Table 6 and it was concluded that it is not possible to reject the assumption of higher unpredictability and consequently higher imbalance volumes and costs offshore. However it is important to keep in mind that the difference is not that large and that the study is performed on a small population of five locations. Second, one can argue that offshore prediction tools are relatively new and more improvement in accuracy is expected in comparison with more mature onshore prediction tools.

Fig. 3 Geographical representation of the three locations of measurement

TABLE 5
STATISTICAL PARAMETERS OF THE WIND SPEED PREDICTION ERROR

[m./sec.]	DE RAAN	GOEREE	STAVENISSE	WOENSDR.	EINDHOVEN
BIAS	-0,74	-0,87	0,16	0,57	0,65
MAE	2,10	2,01	1,77	1,89	1,81
RMSE	2,70	2,60	2,29	2,35	2,26

TABLE 6
NORMALISED STATISTICAL PARAMETERS CONCERNING IMBALANCE OF AN OFFSHORE WIND POWER PLANT

[%]	DE RAAN	GOEREE	STAVENISSE	WOENSDR.	EINDHOVEN
NBIAS	-5,05	-5,53	1,41	1,11	2,75
NMAE	13,07	12,28	10,76	8,54	8,97
NRMSE	19,39	18,53	16,66	13,13	13,95
NMAX	79,26	89,00	78,96	66,32	80,39

IV. Financial Implications of the Tolerance Margin Support Mechanism

In this section, the financial impact of the tolerance margin is studied for a virtual offshore wind power plant (100 MW). The cost of the mechanism is determined by comparing the scenario with and without tolerance margin. Imbalances resulting from the production deviations of a wind power plant are determined by subtracting the measured production from the predicted (nominated) production. As in this study, only the impact of a wind power plant is researched and not aggregated with any other deviations in the BRP's portfolio, the total imbalance is assumed equal to the wind farm's production deviation.

Imbalance volumes for the "Vlakte Van De Raan" are calculated with the available wind data and power curve. Measured wind speed are obtained from KNMI [9] and day-ahead wind speed predictions (13h00, D-1) were delivered by ECN [10]. As regional normalised power curves are utilised [11], these results can be transposed to other installed capacities (as long as it evaluates a wind park in the same region). Therefore, it may be useful to express the production deviations as well in MWh as in percentage of the yearly production (Table 7).

It was studied that 34,2% of the time, the imbalance falls entirely in the tolerance margin, meaning that the production deviation is lower or equal to 30% of the nominated output. In the final column of Table 7, the yearly imbalance volumes falling under the tolerance margin are reviewed as a percentage of the total imbalance volume: 42,7% of the total imbalance volume falls under the support mechanism.

It has to be emphasized that these imbalances originate from day-ahead nominations. However, in reality, expected deviations after gate closure can be dealt with in different ways. Second, a BRP generally has a portfolio in which opposite deviations (other wind farms, demand, unexpected outages) may reduce the total imbalance. These assumptions result in an overestimation of the imbalances. The first one is dropped in the next section dealing with intra-day predictions.

When the imbalances in Table 7 are charged with the imbalance tariff, this results in cash flows between the TSO and the BRP. These may be positive or negative depending on the direction of the imbalance, respectively if the BRP's position is long or short. The total yearly cash flow is determined by aggregating these imbalance tariffs. The total cost for the TSO (or the final subsidy for offshore generation) of the tolerance margin is consequently calculated as the

TABLE 7
YEARLY IMBALANCE VOLUMES FOR AN OFFSHORE WIND PARK OF 100 MW

	Imbalance Volume		Marge Volume		%
	MWh	% Total Prod.	MWh	% Total Prod.	
Imbalance -	35.231	11,11%	22.003	6,94%	**62,46%**
Imbalance +	79.616	25,11%	26.973	8,51%	**33,88%**
TOTAL	114.847	36,22%	48.977	15,45%	**42,65%**

difference in cash flow between a scenario with and without tolerance margin.

The imbalance tariffs were obtained from Elia and calculated with Belpex DAM electricity prices [12][13]. Applying time series of tariffs for 2008, the yearly cash flows are calculated for the two scenarios. Results in Table 8 show a net transfer from TSO to the BRP. This is explained by its average positive imbalance (surplus) caused by the systematic underestimation of the wind speeds which is shown in the previous section. In this study, the resolution of imbalances is one hour where in reality the imbalance settlement mechanism is accounted on a time-scale of 15 minutes. This may have a slight effect on the accuracy of the results.

The financial impact of the subsidy for 2008 is showed in Table 7 and amounts to €5.422 per offshore installed MW. This cost can also be expressed in euro per offshore production resulting in €1,72 per MWh. This is an additional cost for the TSO as it reduces revenues from imbalance tariffs. For a yearly consumption of 90.000 GWh [14] in 2008 and an installed offshore capacity of 2.000 MW this would result in an increase of the electricity price with 0,12 €/MWh.

The average electricity price in 2008 was 70,62 €/MWh which is exceptionally expensive compared to 2007 (41,78 €/MWh) and 2009 (39,36 €/MWh). This consequently has a large influence on the imbalance prices and calculations were therefore repeated for 2009. Results in Table 9 show smaller cash flows and a decreasing effect on the cost of the subsidy. To examine parameters influencing the financial impact of the support mechanism, it can be expressed as:

$$\begin{aligned} Cost &= Cashflow30\% - CashflowWithout30\% \\ &= x * V * P_{IMB_{TM}} + (1-x) * V * P_{IMB} - V * P_{IMB} \\ &= x * V * (P_{IMB_{TM}} - P_{IMB}) \\ &= x * V * P_E * (P_{TM} - P) \end{aligned} \tag{4}$$

x = fraction of imbalance volume falling under tolerance margin [%]

V = total imbalance volume [MWh]

$P_{IMB_{TM}}$ = price imbalance falling inside tolerance margin

P_{IMB} = price imbalance tariff [€/MWh]

P_E = price electricity [€/MWh]

P_E = price electricity [€/MWh]

P_{TM} = 1,1 / 0,9 [€/MWh]

P ≥ 1,08 / ≤ 0,92 [€/MWh]

With this derivation, it can be concluded that the cost of the support mechanism depends on: the price of electricity which influences the imbalance tariffs; the imbalance volumes determined by the prediction tools and the direction of the imbalance as the subsidy only has a positive value if the imbalance is reinforcing the system imbalance.

TABLE 8
FINANCIAL CASH FLOWS IN 2008 CAUSED BY IMBALANCE SETTLEMENT FOR A WIND FARM OF 100 MW

€	SHORT	LONG	NET	€ /MWh
No 30%	2.752.341	3.500.652	-748.311	
30%	2.753.154	4.044.695	-1.291.542	
TOTAL			542.231	1,71

TABLE 9
FINANCIAL CASH FLOWS IN 2009 CAUSED BY IMBALANCE SETTLEMENT FOR A WIND FARM OF 100 MW

€	SHORT	LONG	NET	€ /MWh
No 30%	1.729.972	1.580.492	149.479	
30%	1.703.842	2.004.192	-300.350	
TOTAL			449.829	1,42

V. Introduction of Intra-day Markets

In this section, the impact on the imbalance volumes and by consequence on the imbalance support scheme is researched when introducing perfectly liquid intra-day markets. This scenario enables the possibility to adapt nominations according to intra-day predictions.

Prediction error was again calculated with forecasts received from the ECN [10]. However, the forecast was received closer to real time (19h00) which should result in more accurate predictions. In Table 10, it can be seen that the effects depend on the used indicator but intra-day predictions improve the RMSE with 4,81% when reviewing the wind speed deviations and 2,99% when reviewing the active power deviation. Total imbalance volume decreases and consequently also the volume falling inside the tolerance margin (Table 11).

The financial impact is that the cost of support is reduced with 3,5% for 2008 and -1,9% for 2009. Impact of these predictions closer to real-time are rather limited. Impact should however increase with closer prediction horizons and when prediction modelling reaches maturity.

TABLE 10
STATISTICAL PARAMETERS OF THE WIND SPEED PREDICTION ERROR AND IMBALANCE ACCORDING INTRA-DAY PREDICTIONS

	Prediction error [m./sec.]		Imbalance [% inst. capacity]	
Bias (Mean)	-0,75	-1,33%	-5,42	+7,33%
Mean Absolute Error	2,01	-4,26%	12,60	-3,60%
Root Mean Square Error	2,57	-4,81%	18,82	-2,94%

TABLE 11
YEARLY IMBALANCE VOLUMES FOR A WIND POWER PLANT OF 100 MW WITH PERFECT INTRA-DAY MARKET

	Imbalance Volume MWh		Marge Volume MWh		%
Imbalance -	31,508	-10,58%	20.647	-6,16%	65,53%
Imbalance +	79,150	-0,59%	26.740	-0,86	33,78%
TOTAL	110,658	-3,65%	47.387	-3,25%	42,82%

TABLE 12
CASH FLOWS CAUSED BY IMBALANCE SETTLEMENT WITH PERFECT INTRA-DAY MARKETS FOR A WIND POWER PLANT OF 100 MW

€	2008		2009	
No 30 %	-1.059.111		-30.788	
30 %	-1.582.394		-472.081	
SUPPORT	523.283	-3,49 %	441.294	- 1,90 %
Per MW	5.233		4.413	
Per MWh	1,65		1,39	

VI. CONCLUSIONS

The aim of this paper is to review a specific Belgian regulation installing a tolerance margin for offshore production deviations leading to imbalances. Inside this margin of 30% of the nominated output, beneficial imbalance tariffs are enjoyed. Incentive is however maintained for the BRP to minimise imbalance volume and this support mechanism is creates only a financial compensation without worsening the impact on grid security.

A preliminary study with five offshore and onshore locations confirms the argumentation of lower predictability offshore with prediction errors (RMSE) being 2-6% higher for offshore locations. Consequently, this increases imbalance costs and reduces market value of offshore wind power.

Although this support mechanism can be defended as it directly tackles the imbalance cost, this regulation is anything but transparent. The complexity of the execution of this regulation raises the question if this support mechanism for offshore wind generation could not be replaced by other easier, transparent support mechanisms. The same support effect could for instance be achieved by increasing the minimal price of the green certificates received for renewable generation.

The financial impact of the support mechanism was calculated by attaching the applicable tariff (based on the electricity price) on the imbalance volume. This results in €5.422 per installed MW of offshore capacity in 2008 which corresponds to a subsidy of €1,71 per offshore generated MWh. If for a wind park of 2 GW, this subsidy is passed towards the consumer trough transmission tariffs this would results in a increase of the price of electricity with €0,12 per consumed MWh. This subsidy increases with electricity price, the frequency of wind park imbalances reinforcing the system imbalance and the imbalance volume. When the same subsidy was calculated for a year with lower electricity prices (2009), this results in €4.498 per installed MW and €1,42 per produced MWh.

When intra-day markets are enabled to correct nominations according to new predictions received after gate closure, this is expected to reduce imbalance volume, costs and the financial cost of the subsidy. Calculations were made for a received prediction update at 18h00. This results in a maximal decrease of RMSE of 3% leading to a 3,5% (2008) - 1,9% (2009) reduction in the subsidy per produced MWh.

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REFERENCES

[1] Vandezande, L., Meeus, L., Belmans, R. Saguan, M., Glachant, J. (2009) "Well-functioning balancing markets: A prerequisite for wind power integration", *Energy Policy In Press, Corrected Proof.*

[2] De Vos, K. and Driesen, J. (2008) "Balancing Management Mechanisms for Intermittent Power Sources" EEM'09, Belgium, IEEE

[3] Elia System Operator "Imbalance tariffs", www.elia.be, accessed in December 2009

[4] Millgan, M, Porter, K., DeMeo, E. et al. (2009) "Wind Power Myths Debunked" IEEE power & energy magazine, Vol. 7 (6), November – December 2009, pp. 89-99.

[5] Belgisch Staatsblad, publicatie: dinsdag 31 maart 2009, derde editie "Koninklijk besluit betreffende productieafwijkingen op installaties voor de productie van elektriciteit uit wind in de zeegebieden"

[6] CREG (2008), "Advies over het ontwerp van koninklijk besluit betreffende productieafwijking op installaties voor de productie van elektriciteit uit wind in de zeegebieden", 20 juni 2008, (A)080620-CDC-771

[7] Ackermann, T. , Abbad, J., Dudurych, I., Erlich, I., Holttinen, H., Kristoffersen, J., Sorensen, P. (2007) "European Balancing Act" *IEEE Power and Energy Magazine*, vol. 5, 2007, pp. 90-103.

[8] De Vos, K., Driesen, J., Belmans, R. (2010) "Imbalance Settlement Mechanisms of Offshore Wind Power Producers", Young Researchers Symposium, Belgium, 2010.

[9] Koninklijk Nederlands Meteorologisch Instituut (2009) "Potential Wind Speeds of the Netherlands", www.knmi.nl, last consulted 15/5/2009

[10] Brand, A., Kok, J. (2003), "Aanbodvoorspeller duurzame energie – Deel 2: Korte-termijn prognose van windvermogen", Juni 2003 ECN-C--03-049

[11] TradeWind (2008) "WP2.6 – Equivalent Wind Power Curves" Garrad Hassan and Parners Ltd, 15 July 2008, www.trade-wind.eu, last consulted on 06/01/2

[12] ELIA, Operational Data & Tools, Imbalance tarrifs, www.elia.be, last consulted: January 2010

[13] Belpex, market data www;belpex.be, last consulted: January 2010

[14] ENTSO-E, "Detailed Monthly Production (in GW) (Database: 18.01.2010)", www.entsoe.eu, last consulted: January 2010